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Cameron M. Smith
Portland State University, b5cs@pdx.edu

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b5cs@pdx.edu
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Abstract

Pacific Spaceflight's Mark II pressure garment (model *Gagarin*) was test flown to 17,200 feet MSL (5,242m) while worn and operated by Dr. C.M. Smith. The garment and its portable life support system (PLSS) maintained appropriate pressure, temperature and carbon dioxide levels throughout the 47-minute flight. The suit also provided sufficient elbow mobility, due to its convolute joints, for the suited person to operate the portable life support system's manual suit pressure setting valve and the hand-held radio.

1. Introduction

In Summer 2013 Pacific Spaceflight members CM Smith and JF Haslett tested the Mark I pressure garment (model *Tsiolkovski*) in a hypobaric chamber at the Copenhagen University Hospital, Denmark. In that test, a simulated altitude of 13,000 FT MSL (c.4,000m) was produced in the chamber, and the suit occupant's blood oxygenation and pulse were recorded for a roughly 36-minute 'flight' during which suit pressure and temperature were suitably maintained, and blood oxygenation remained above 90%, a figure expected for an altitude of 8,500 FT MSL (2,590m) [1]. This proved the essential function of the pressure garment, that of stably maintaining a lower perceived altitude inside the suit than the ambient (simulated pressure) altitude.

Following that test, from January - March 2014 constant-volume convolute elbow sections were designed, built and tested (**Figure 1**) and in April 2014, installed in the Mark I suit, graduating it to Mark II status (model change to *Gagarin*) (**Figure 2**). To continue the overall Pacific Spaceflight plan of gradually increasing the altitude at which our pressure garments are tested, it was decided in May 2014 to make an ascent to c.25,000 FT MSL in a local aircraft.

Making the ascent in an aircraft rather than altitude chamber was also planned to begin gaining experience in flight planning and operations. For record-keeping purposes, the flight discussed in this report is referred to as Test Flight 2014-1.

2. Events

On 23 August 2014 the Pacific Spaceflight team composed of CM Smith, AW Knapton, B Wilson, K MacAllister, A Magruder and R Kraft, accompanied by a professional film team from VICE media and aviator-cameraman D.O'Bryan (who would serve as Flight Safety Officer), transported Pacific Spaceflight's Mark II pressure garment (model *Gagarin*) to JL Aviation in Boring, Oregon. There, JL Aviation Services was contracted to fly the suit, with a person inside, and the portable life support system (PLSS) to an altitude approximating the service ceiling of the Bell 206 Jet Ranger, c.20,000 FT MSL (the 25,000 FT MSL aircraft not being available). Due to the ambient temperature and other factors, the JL aviation pilot estimated that we could reach about 18,000 FT MSL, and that he would try to take us as high as safely possible; in the event, 17,200 FT MSL was the maximum altitude attained.

Figure 3 indicates the essential configuration of the pressure garment and the PLSS in the back seat of the Bell 206 Jet Ranger and **Figure 4** shows the actual PLSS.

In **Figure 3**, the test subject is supplied by Portable Life Support System (PLSS) using normal air (c.20% oxygen, c.80% nitrogen) as the breathing gas, delivered from a standard 82 cubic-foot aluminum SCUBA tank pressurized to c.2,800PSI and secured to the PLSS frame (1). This breathing gas was delivered through a pressure-reducing manifold and handactuated flowmeter where (2) it was set to 28 liters (60 cubic feet) per minute (a rate unchanged through the test), delivered to the to the helmet (3) by a hose; inside the helmet, breathing gas was routed by hoses such that some blew towards the mouth while the remainder was blown down and onto the interior of the visor to prevent fogging (this was effective). Exhaled gas was vented from the suit through a thigh port (4) that led, via a hose, to the pressure setting needle valve; by adjusting the setting needle, the gas allowed to exit the suit was regulated and the desired suit pressure (indicated on a 5 PSI WIKA pressure gauge mounted on the PLSS) maintained; this dumped suit gas flowed past a carbon dioxide monitor (model RAD030) to monitor carbon dioxide levels in the suit gas. The left thigh was also furnished with an automatic overpressure valve set to open at 4.0 PSI and a manually-activated emergency pressure release valve. Communication was via hand-held Motorola *Talkabout* walkie-talkie; this lasted for the first 3 minutes of flight, after which communication was lost; contact was made again in last few minutes of approaching the landing tarmac.

Figure 5a shows the installation of the PLSS in the Jet Ranger's rear starboard seat; a hacksaw was used to shorten some elements, a good reminder of the importance of carrying a full tool kit to each field operation. While the PLSS was installed, Dr. Smith was suited by A Magruder, the PLSS was powered and checked by AW Knapton, and Dr. Smith was installed in the rear port seat (**Figure 5b**). Aviation student and aerial cameraman D O'Bryan sat in the front left seat as the Flight Safety Officer, the helicopter being flown by Peter M. Emerson, Director of Maintenance & Lead Pilot/Company Instructor Pilot of JL Aviation, Inc, Boring, Oregon. On several occasions D. O'Bryan visually checked in with Dr. Smith, who hand-signaled "A-OK" as the two did not have a radio link.

Takeoff (**Figure 7**) occurred just past local noon. **Figures 8** and **9** (a crude transcription of the suit voice recorder into which Dr. Smith made a running commentary through the flight) indicates that in just under 30 minutes, the maximum altitude of c.17,200 feet was attained; at this point Dr. Smith reported a suit pressure of 2.3 PSI and a good CO2 figure of <300 PPM and generally reported "all well", which was consistent through the 47-minute flight.

3. Results

3.1 Breathing Gas Delivery

Normal air was used as the breathing gas in this test, although pilot Emerson and Flight Safety Officer O'Bryan breathed 100% Aviators Breathing Oxygen in a diluted from from oral-nasal masks fed by a Sky-Ox SKY-10460 regulator that was manually set by D. O'Bryan at various altitudes to deliver the proper volume of gas. The transcripts in **Figures 8** and **9** indicate that Dr. Smith reported a good rate of breathing gas delivery throughout the flight. Occasionally, perhaps due to nervousness, breathing gas was inhaled deeply from the opening where it was diverted towards the mouth; longer tests will determine whether this was due to a genuine deficiency of delivered breathing gas (a blood oxygenation monitor, noted in **Section 3.3**, will also be used in all following tests).

3.2 Suit Pressure Maintenance

Table 2 indicates the pressure schedule set for the ascent to 17,000 feet and **Table 2** the pressure schedule for descent. This schedule was designed based on fight physiology data [2] to prevent Altitude Decompression Sickness by use of suit pressure to keep the body physiologically at 'low' altitude. The various pressures were maintained during flight by Dr. Smith manually operating the suit dump valve (a needle valve) according to settings noted on a card posted clearly in view (**Figure 10**). During ascent, vertical speed (often about 800 feet per minute) was low enough to keep up with the settings, but sometimes on the rather faster descent Dr. Smith noted difficulty in keeping track of his C02 levels, breathing gas tank pressure, proper suit pressure setting, attempts at communications, and general awareness of the flight situation. This observation indicates the importance of simulations to accustom the eventual high altitude balloon flight pilot to such information-rich environments.

Figure 11 indicates the essential flight pressures against altitudes and time. The highest suit pressure was between 2.3 PSI and 2.5 PSI, while most of the flight was carried out at pressures between 1.2 PSI and 2.0PSI. The suit maintained these pressures with no audible or otherwise evident leaks. At the flight apogee of 17,200 FT MSL, the suit pressure of 2.3PSI was added to the ambient pressure of 7.6 PSI for a total suit pressure of 9.9 PSI, yielding a physiologically-perceived altitude of 10,500 FT MSL, an altitude 6,500 feet below the 17,000 FT MSL altitude threshold where altitude decompression sickness typically begins for unacclimated aviators [2], normally after some 10's of minutes of exposure.

Just before takeoff it was noticed that even with the suit pressure regulator needle valve at the fully-open position, suit gas was not being vented. This was fixed by adjusting the leg inside the suit so that the thigh did not block the gas dump port; this was another instance of a recurring problem that has been dealt with in Summer 2014 by entirely removing gas dump fittings from the thighs and movement to the mid-torso area for clear venting.

3.3 Carbon Dioxide Levels

Figure 12 indicates C02 levels in the 900's PPM below 12,000 feet and a significant drop below this, into the sub-300 PPM levels above 15,000 feet, only rising slightly by the time of landing. Generally speaking, C02 PPM levels above 400 are abnormal outdoors, but they may rise to c.1,000 PPM without cognitive detriment in office buildings, and a report by the National Academies Press allows for 8,000PPM in military submarines [3]. **Figure 11** recapitulates findings of Satish et al., who reported normally mild cognitive impairment at levels below 2,500 PPM, though with some exceptions [4]; Pacific Spaceflight is currently researching C02 levels and designing solutions including high suit gas flowthrough rates and a prototype C02 scrubbing system, which is complete in prototype form as of November 2014 and ready for testing in early 2015; also ready at this time, but not at the time of the flight, is a blood oxygenation monitor and data-logger.

3.4 Suit Temperature

Suit temperature was maintained by circulating a coolant fluid through the suit's coolant garment via the 12v DC PLSS pump. Days before the flight test the suit and PLSS had been tested in a frozen food chamber in Washougal, Washington, at -20F / -28C, during which the thermal mitigation fluid (warm water) quickly froze in the PVC hoses (a report of this test is in production). After adding granulated sugar as an antifreeze the system performed well in the freezing chamber, so commercial antifreeze was added in low concentration during the flight test. While ambient temperature at 17,000 FT MSL was roughly -1.6F / -18C, the coolant fluid flowed well and a very comfortable suit-interior temperature was maintained throughout the flight.

3.4 Suit Mobility

Throughout the flight the suit's convolute elbow sections provided significantly easier flexion of the forearm than the Mark I garment's simple gastight cylinder-sleeves. Though the Mark II butyl convolutes are heavy, and heavily reinforced with steel cables and tubular nylon webbing and other materials, they were designed as proof-of-concept items not for the eventual high altitude flight. In terms of remaining gastight and mobile at high pressure, and under control of the restraint mesh, the convolute elbows proved to be a successful solution to the problem of forearm mobility at suit pressure exceeding about 1.8 PSI.

4. Commentary

The test flight was an excellent operation in terms of both suit performance and planning and execution. The crew successfully installed the PLSS and Dr. Smith into the pressure suit and the helicopter, communications were good until range was too great, and all systems functioned well, resulting in a comfortable and trouble-free flight. This was only the case because of weeks of intensive preparations and check-outs of the various hardware, checklists and plans.

For further flight tests before the balloon flights scheduled for later 2015, Table 4 indicates some air operators and their capabilities in the immediate Portland area.

5. References

[1] Smith, C.M. 2013. Pacific Spaceflight Research Brief #2013-1: *Hypobaric Chamber Test of Pacific Spaceflight Pressure Garment Mark I at Copenhagen University Hospital.* Online at https://www.academia.edu/5414347/Hypobaric_Chamber_Test_of_Pacific_Spaceflight_Pressure_Garment_Mark_I_at_Copenhagen_University_Hospital.

[2] Smith, C.M. 2013. Pacific Spaceflight Research Brief #2013-2: *Review of High Altitude Aviation Preoxygenation / Denitrogenization Procedures andDraft Pressure Schedule for Open-Cockpit Balloon Flight to 65,000 Feet.* Online at http://www.academia.edu/5414350/Review_of_High_Altitude_Aviation_Preoxygenation_Denitrogenization_Procedures_and_Draft_Pressure_Schedule_for_Open-Cockpit_Balloon_Flight_to_65_000_Feet.

[3] National Academies Press. 2007. Emergency and Continuous Exposure Guidance Levels for Selected Submarine Contaminants. Online at http://www.nap.edu/catalog/11170/emergency-and-continuous-exposure-guidance-levels-for-selected-submarine-contaminants.

[4] Satish, U. et al. 2014. Is CO2 an Indoor Pollutant? Direct Effects of Low to Moderate CO2 Concentrations on Human Decision?Making Performance. *Environmental Health Perspectives.* Online at doi:10.1289/ehp.1104789.

Table 1. Provisional Schedule of Activities for Crew Members on Flight Day. Note plan here was for flight to 25,000 FT MSL, and included a prebreathing period that was not carried out on the flight reported in this file. MOL=Molalla, Oregon, unusued site of first planned flight.

TIME	GENERAL ACTIVITY	SUIT PLT (CMS)	SUIT TECH 1 (BW)	SUIT TECH 2 (AM)	PLSS TECH 1 (AK)
Flight - 5 hours	Move gear Portland - airstrip	PDX-MOL	PDX-MOL	PDX-MOL	PDX-MOL
Flight - 4 hours	Arrive airstrip, stage gear	Stage Gear	Stage Gear	Stage Gear	Stage Gear
Flight - 3 hours	Preflight preparations	Review flight plan	Suit Preparation Checklist	Suit Preparation Checklist	PLSS Prepara-tion Checklist
Flight - 2 hours	Preflight preparations	Don Suit	Suitup Checklist	Suitup Checklist	PLSS Install in Aircraft Checklist
Flight - 1 hour	Preflight preparations	Prebreathe / Review revised flight plan	Prebreathe Checklist	Prebreathe Checklist	PLSS final checkout
Flight - 40 min	Move to aircraft	Take seat	Install PLT in aircraft	Install PLT in aircraft	Standby
Flight - 30 min	Final Checks	Comm check	Standby	Standby	Standby
Flight - 10 Min	Begin Flight Test	Respond to CAP-COM	Standby	Standby	Standby
Flight	Flight Test	Respond to CAP-COM	Standby	Standby	Standby
Flight + 40 min	Arrive apogee, begin descent	Respond to CAP-COM	Stage gear for extracting PLT	Stage gear for extracting PLT	Stage gear for extracting PLSS
Flight + 60	Landing	Disconnect from ship systems	Extract PLT from aircraft	Extract PLT from aircraft	Extract PLSS from aircraft
Flight + 70	Deplane	Suit Doff	Suit Doff	Suit Doff	Pack PLSS
Flight + 80	Destage / Pack for Transport	standby	standby	standby	standby
Flight + 90	Move gear to Portland	standby	standby	standby	standby

TABLE 2. Pressure Suit Pressure Schedule for Ascent to 25,000 FT MSL. ALT=Feet MSL, APSI=Ambient Pressure in PSI, SUIT PRESS=Suit Pressure Setting in PSI, PHYS PRESS=Pressure felt by body in PSI, SUIT ALT=Body's Perceived Altitude in FT MSL.

ASCENT

ALT	APSI	SUIT PRESS	PHYS PRESS	SUIT ALT
0	14.7	0.5	15.2	-200
500	14.4	0.5	14.9	-100
1000	14.2	0.5	14.7	250
1500	13.9	0.5	14.4	500
2000	13.7	0.5	14.2	1000
2500	13.4	0.5	13.9	1500
3000	13.2	0.5	13.7	2000
3500	12.9	1.0	13.9	1500
4000	12.7	1.0	13.7	2000
4500	12.5	1.0	13.5	2200
5000	12.2	1.0	13.2	3000
5500	12.0	1.0	13.0	3400
6000	11.8	1.0	12.8	3800
6500	11.6	1.5	13.1	3000
7000	11.3	1.5	12.8	3700
7500	11.1	1.5	12.6	4200
8000	10.9	1.5	12.4	4600
8500	10.7	1.5	12.2	5000
9000	10.5	1.5	12.0	5500
9500	10.3	1.8	12.1	5000
10000	10.1	1.8	11.9	5800
10500	9.9	1.8	11.7	6200
11000	9.7	1.8	11.5	6700
11500	9.5	1.8	11.3	7000
12000	9.3	1.8	11.1	7500
12500	9.2	1.8	11.0	7600
13000	9.0	1.8	10.8	8200
13500	8.8	1.8	10.6	8700
14000	8.6	1.8	10.4	9200
14500	8.5	1.8	10.3	9500
15000	8.3	1.8	10.1	10000
15500	8.1	1.8	9.9	10500
16000	8.0	1.8	9.8	10700
16500	7.8	1.8	9.6	11250
17000	7.6	2.3	9.9	10500
17500	7.5	2.3	9.8	10700
18000	7.3	2.4	9.7	11000
18500	7.2	2.4	9.6	11200
19000	7.0	2.6	9.6	11500
19500	6.9	2.7	9.6	11250
20000	6.8	2.8	9.6	11250
20500	6.6	3.0	9.6	11250
21000	6.5	3.0	9.5	11500
21500	6.3	3.0	9.3	12000
22000	6.2	3.0	9.2	12500
22500	6.1	3.0	9.1	12700
23000	5.9	3.0	8.9	13250
23500	5.8	3.0	8.8	13500
24000	5.7	3.0	8.7	13700
24500	5.6	3.0	8.6	14200
25000	5.5	3.0	8.5	14500

TABLE 3. Pressure Suit Pressure Schedule for Descent from 25,000 FT MSL. ALT=Feet MSL, APSI=Ambient Pressure in PSI, SUIT PRESS=Suit Pressure Setting in PSI, PHYS PRESS=Pressure felt by body in PSI, SUIT ALT=Body's Perceived Altitude in FT MSL.

DESCENT

ALT	APSI	SUIT PRESS	PHYS PRESS	SUIT ALT
24500	5.6	3.0	8.6	14200
24000	5.6	3.0	8.6	14200
23500	5.7	3.0	8.7	13700
23000	5.8	3.0	8.8	13500
22500	5.9	3.0	8.9	13250
22000	6.1	3.0	9.1	12700
21500	6.2	3.0	9.2	12500
21000	6.3	3.0	9.3	12000
20500	6.5	3.0	9.5	11500
20000	6.8	2.8	9.6	11250
19500	6.9	2.7	9.6	11250
19000	7.0	2.6	9.6	11250
18500	7.0	2.6	9.6	11250
18000	7.3	2.4	9.7	11000
17500	7.3	2.4	9.7	11000
17000	7.6	2.3	9.9	10500
16500	7.6	2.3	9.9	10500
16000	7.8	2.3	10.1	10000
15500	8.0	2.3	10.3	9500
15000	8.1	2.3	10.4	9200
14500	8.3	2.3	10.6	8700
14000	8.5	1.8	10.3	9500
13500	8.6	1.8	10.4	9200
13000	8.8	1.8	10.6	8700
12500	9.0	1.8	10.8	8200
12000	9.2	1.6	10.8	8200
11500	9.3	1.6	10.9	8000
11000	9.5	1.6	11.1	7500
10500	9.7	1.6	11.3	7000
10000	9.9	1.6	11.5	6700
9500	10.3	1.5	11.8	6000
9000	10.3	1.5	11.8	6000
8500	10.5	1.5	12.0	5500
8000	10.7	1.5	12.2	5000
7500	10.9	1.5	12.4	4700
7000	11.1	1.1	12.2	5000
6500	11.3	1.1	12.4	4700
6000	11.6	1.1	12.7	4000
5500	11.8	1.1	12.9	3500
5000	12.0	1.1	13.1	3250
4500	12.2	1.1	13.3	2700
4000	12.5	0.7	13.2	3000
3500	12.7	0.7	13.4	2500
3000	12.9	0.7	13.6	2250
2500	13.2	0.7	13.9	1500
2000	13.4	0.7	14.1	1700
1500	13.7	0.7	14.4	500
1000	13.9	0.7	14.6	150
500	14.2	0.7	14.9	-100
0	14.7	0.5	15.2	-200

TABLE 4. Flight Operators and Options Local to Portland, Oregon.

SITE	Distance	Aircraft to Rent	Aircraft Ceiling	Cost Per Hour	Web	Phone	Email	Address
Konect Aviation McMinnville	1 hour	Robinson R22 (helo) Robinson R44 (helo) Cessna 172 Single	14000 14000 13500	not rental, tour only (?) not rental, tour only (?) not rental, tour only (?)	http://www.konect-aviation.com/	503-376-0190	none	Konect Aviation 4040 SE Cirrus Ave McMinnville, OR 97128
Fly-Oregon (Twin Oaks Airport) Portland	30 min	Piper Comanche Piper Aztec Twin Piper Geronimo Apache Twin (down for repairs)	19500 18950 18950	185 260 219	http://twinoaksairpark.com/	(503) 348-2027 503-451-3480	kwiprud@gmail.com	Twin Oaks Airpark 12405 SW River Rd Hillsboro, OR 97123
Gorge Winds Aviation Troutdale	 1 hour	Cessna 310Q Twin Cessna 182 Single	20000 18100	297 178	 http://www.gorgewindsinc.com/	503-661-1044 503-665-2823		Gorge Winds Aviation 920 NW Perimeter Way Troutdale, OR 97060
Aurora Aviation Aurora	30 min	Beechcraft Baron Twin Piper Seminole Twin Cessna 172 Single Cessna 162 Single	19700 15000-17000 13500 14625	not listed for rental (?) not listed for rental (?) 113 113	http://auroraaviation.com/	(503)678-1217	office@auroraaviation.com	Aurora Aviation 22785 Airport Road NE Aurora, Oregon 97002
Aero Maintenance Flight Center Vancouver, Washington	1 hour	Cessna 150 Single Cessna 172 Single Piper Cherokee Single	14000 13500 14300	70 120 130	http://www.aeromt.com/	360-735-9441	none	Aero Flight Center 101 E Reserve St. Vancouver, SA 98661
Wilamette Aviation Service	1 hour	Piper Cherokee Single Piper Apache Twin Cessna 177 Single Cessna 172 Single Diamond DA40 Diamond Star Single	14300 18950 14600 13500 16400	139 282 188 163 191	http://www.willametteair.com/	503-678-2252	info@willametteair.com	Willamette Aviation Service 23115 Airport Road NE Aurora, OR 97002
Spana Flight Puyallup, Washington (just south of Tacoma)	2 hours	Piper Cherokee Arrow Single Cessna 152 Single Cessna 172 Single	16000 14700 13500	164 93 122	http://www.spanaflight.com/	253-848-2020	flight@spanaflight.com	SpanaFlight 16705 103rd Avenue Court East Puyallup, Washington 98374
JL Aviation Boring, OR	1 hour	Bell Jet Ranger Bell Long Ranger	20,000 13,500	1,000 1,000	http://www.jlaviation.net	503-249-2770	info@jlaviation.net	JL Aviation PO Box 515 Boring, OR 97009 PHONE: (503) 249-2770 FAX: (503) 663-9764

FIGURE 1. Video Frames of Constant Volume Convolute Elbow Joint Being Flexed and Extended Without Difficulty at 3.5 PSIG; upper frames include team member W Magruder and lower, Dr. CM Smith. Video is online at https://www.youtube.com/watch?v=j5gI36VwuHM&list=UUup7MB9ZJJMGYd2NVkK_kJQ.

FIGURE 2. Finished Constant Volume Elbow Joint (left) and Joints Installed in Pressure Garment (right).

FIGURE 3. Essential Configuration of the Pressure Suit and Portable Life Support System in Bell 206 Jet Ranger.

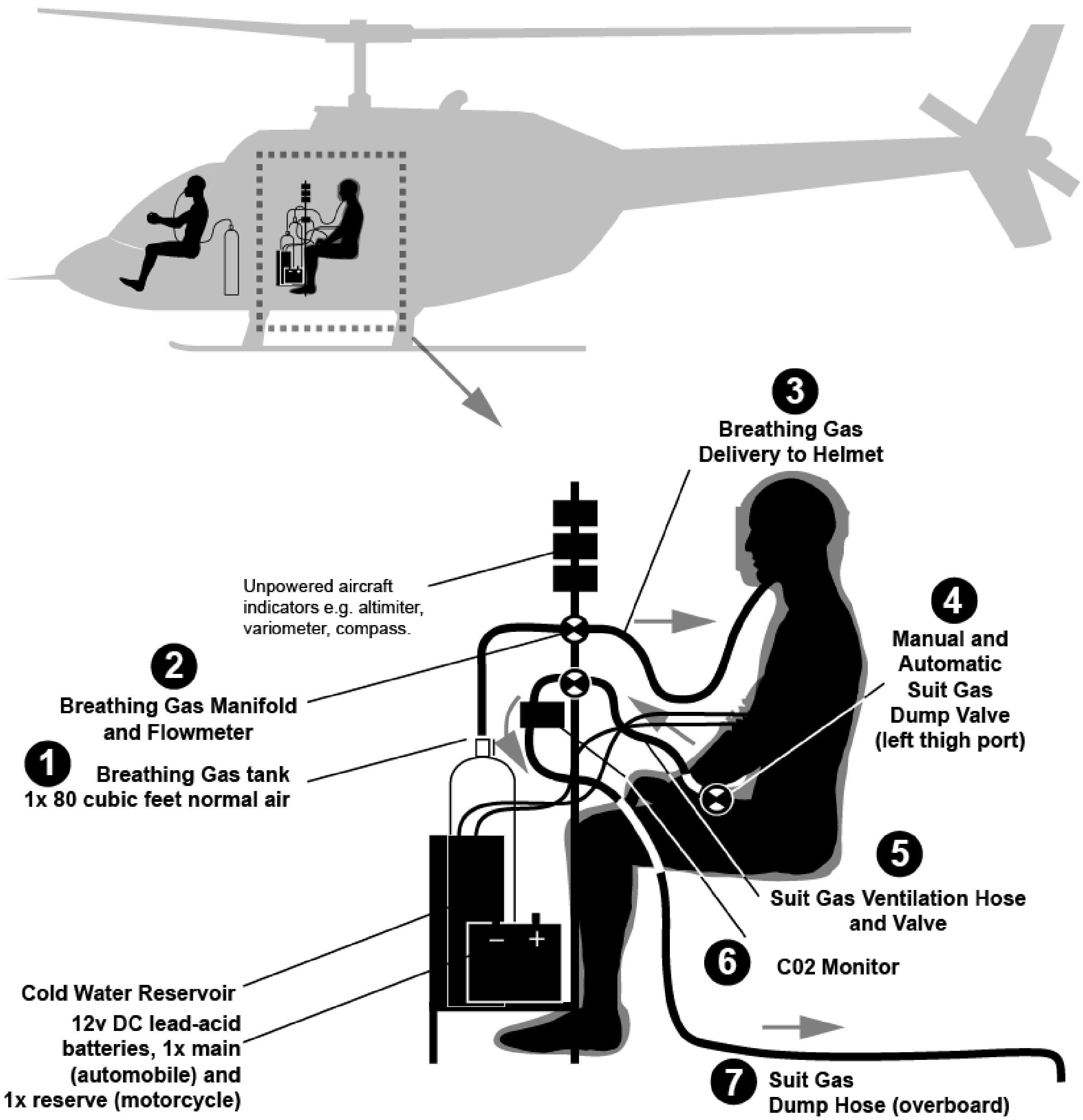
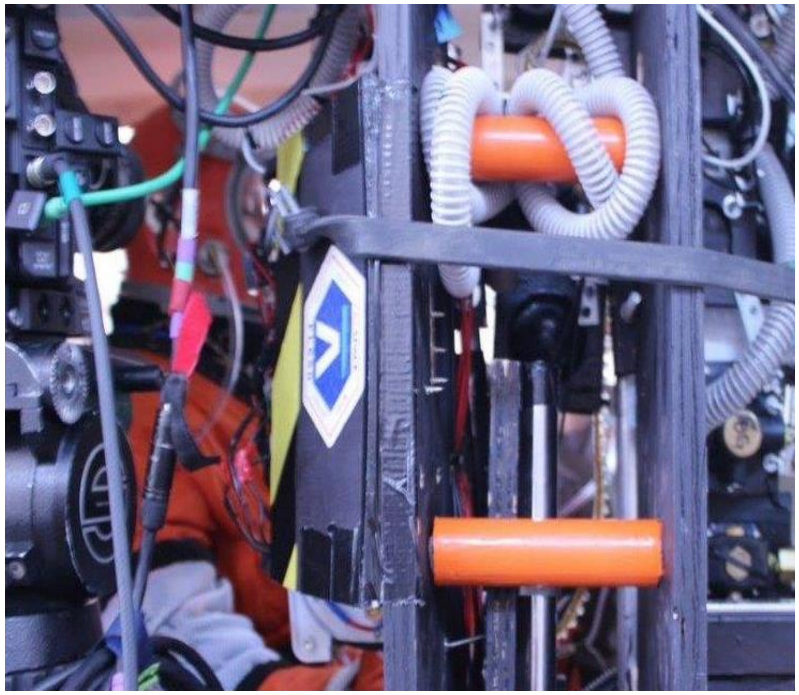


FIGURE 4. Pacific Spaceflight Crewmember AK Knapton With the Portable Life Support System (PLSS) Prepared for Use in Bell 206 Jet Ranger, Before Custom Fitting. SCUBA tank noted in Figure 3 not installed in this photo. This stripped-down PLSS manifestation was named 'Skeletor' as it was significantly reduced in bulk and weight from prior builds.

FIGURE 5. (A) Impromptu Custom Fitting of PLSS to Bell 206 Jet Ranger's Starboard Rear Seat by Pacific Spaceflight Team Members B Wilson, K MacAllister and R Kraft, and Dr. Smith Installed in the Rear Seat (B).

A



B

FIGURE 7. Helicopter Fuelling and Final Preflight Preparations (A) and Takeoff (B).

A

B

FIGURE 8. Transcript of Audio Record of Ascent Phase of Test Flight.

MP3 Time	Flight Time	Event	ALT	Suit Temp	Suit Press	Suit Humidity	Coolant Temp	C02	BG Tank Press	Volts	Amps	Ascent/Descent Rate	Comment
7m27sec	-	Visor Down	-	21.9C/71.2F	0.5	-	-	-	2600	-	-	-	-
19m30sec	-	Engine Start	0	-	-	-	-	-	-	-	-	-	-
22m49sec	-	-	1000	good	1	-	-	good	-	-	-	-	-
24m30sec	-	-	2000	-	-	-	-	-	-	-	-	-	all well
25m55sec	-	-	4400	good	1.5	-	41.6F	989	-	-	-	-	AOK from Duncan, bad comms with ground
26m49sec	10m27sec	-	5400	-	1	-	-	-	-	-	-	-	-
27m33sec	-	-	-	-	-	-	-	-	-	-	-	-	comm check (no reply)
28m28sec	11m59sec	-	7000	good	1.1	-	-	992	2000	-	-	-	-
29m09sec	-	-	7500		1.7	-	-	-	-	-	-	-	-
29m36sec	-	-	9000		1.9	-	-	-	-	-	-	-	-
30m25sec	14m20sec	-	10000	22.6C / 74.8	2	-	-	910	-	-	1	Plus 1000	
31m08sec	-	-	10000	-	-	-	-	-	-	-	-	-	all well
31m42sec	-	-	9900	-	1.8	-	-	-	-	-	-	-	-
31m58sec	-	-	10200	-	2.2	-	-	-	-	-	-	-	-
32m22sec	-	-	10500	-	2.2	-	-	-	-	-	-	-	-
32m55sec	16m00sec	-	11000	-	1.8	-	-	-	-	-	-	-	-
33m48sec	-	-	12000	-	-	-	-	-	-	-	-	-	slightly choppy air (turbulence)
34m39sec	18m20sec	-	12000	-	2	-	-	-	-	-	-	-	-
35m19sec	19m00sec	-	14000	-	2.5/2.4	-	-	-	1700	-	-	-	-
36m40sec	20m00sec	-	14000	-	2	-	-	-	-	-	-	-	all well
37m45sec	-	-	-	-	-	-	-	-	-	-	-	-	comm check (picking you up but garbled)
38m11sec	-	-	15000	-	-	-	-	-	-	-	-	-	(garbled comms from ground)
39m00sec	-	-	-	-	-	-	-	-	-	-	-	-	comm check (picking you up but garbled)
39m20sec	-	-	15000	-	-	-	-	-	-	-	-	-	-
39m49sec	23m00sec	-	15000	24.2C/79F	1.8	82.00%	36.6F	green	-	-	-	-	(garbled comms from ground)
41m00sec	24m00sec	-	15000	-	1.5	84.00%	-	good	-	-	-	Plus 500	-
42m54sec	26m00sec	-	16000	-	2.5	-	-	-	1500	-	-	-	everything's good, feeling good
43m14sec	-	-	16100	-	-	-	-	-	-	-	-	Plus 200	ascent rate has slowed dramatically, some turbulence
44m41sec	28m00sec	-	16450	82F	2	-	38F	298	1100	-	-	-	bringing suit pressure to 2.3
48m01sec	-	-	17000	-	2.3	-	-	250	1000	-	-	Plus 1000	all well
49m35sec	-	-	17000	-	-	-	-	-	-	-	-	-	comm check (no reply)
50m00sec	-	-	-	25.4C/77.7F	2.5/2.4	88.00%	-	-	-	-	-	-	all well, beginning descent
50m35sec	-	-	-	36.0C/96.8F	-	-	-	215	-	-	-	-	-

FIGURE 9. Transcript of Audio Record of Descent Phase of Test Flight.

50m35sec	-	-	-	36.0C/96.8F	-	-	-	215	-	-	-	-	-
51m21sec	-	-	15000	2.5.5C/75F	2.5	-	-	-	-	10	1	-	all well, very comfortable
52m18sec	-	-	15000	-	2	-	-	-	-	-	-	Minus 1000	-
52m58sec	36m00sec	-	15000	83.6F	2		39.2F	168	-	-	-	Minus 1400	-
53m33sec	-	-	-	-	-	-	-	-	-	-	-	-	comm check (no reply)
54m13sec	38m00sec	-	14000	21.1C/71.4F	1.8	-	37.6F	400's	>1000	10	<1	Minus 1800	fast descent
55m18sec	-	-	-	-	-	-	-	-	-	-	-	-	comm check (no reply)
55m32sec	-	-	-	-	-	-	-	-	-	-	-	-	comm check (no reply)
55m53sec	-	-	11000	68.3F	2	-	-	green	-	10	<1	-	feeling very frosty (in a good sense)
56m44sec	40m00sec	-	10000		0.9	-	39.6F	low	>1000	-	-	Minus 2000	-

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57m30sec	-	-	-	-	-	-	-	-	-	-	-	-	comm check (no reply)
57m40sec	-	-	-	-	-	-	-	-	-	-	-	-	comm check (no reply)
57m45sec	-	-	-	-	-	-	-	-	-	-	-	-	comm check (no reply)
58m02sec	41m02sec	-	6000	-	1	84.00%	-	-	-	-	-	-	all well sign from Duncan
58m36sec	-	-	-	-	-	-	-	-	-	-	-	-	comm check (no reply)
58m50sec	-	-	-	-	-	-	-	-	-	-	-	-	comm check (no reply)
59m45sec	-	-	-	-	-	-	-	-	-	-	-	-	comm check (no reply)
59m50sec	-	-	-	-	-	-	-	-	-	-	-	-	comm check (no reply)
1h00m27sec	-	-	-	23.2C/73.7F	-	-	41.8F	good	-	10	<1	Minus 1000	-
1h01m03sec	44m00sec	-	-	-	-	-	-	-	-	-	-	-	comm check (no reply)
01h01m54sec	-	-	-	-	-	-	-	-	-	-	-	-	comm check (no reply)
01h02m05sec	45m00sec	-	<1000	20.3C/68.5F	0.5	82.00%	40F	-	<1000	-	-	-	banking left to landing zone
01h03m00sec	-	-	-	-	-	-	-	-	-	-	-	-	comm check (no reply)
01h03m10sec	-	-	-	-	-	-	-	-	-	-	-	-	comm check (no reply)
01h03m35sec	-	Engine Off	-	-	-	-	-	-	-	-	-	-	comm check (no reply)
01h04min00sec	47m00sec	-	-	21.6C/70F	0.5	84.00%	39F / 41.5	378	800	-	<1	-	comm check (back in comms)
01h05min00sec	-	-	-	21.4C/70.5	0.5	84	42	-	-	-	-	-	back in comms
01h12m14sec	-	Visor Up	-	-	-	-	-	-	-	-	-	-	-

FIGURE 10. Pressure Setting Card Indicator Posted in Prominent View of Suit Operator During Flight.

ALT Feet MSL	F	PSI	SUIT PRESS	SUM PRESS	SUIT ALT Feet MSL
ASCENT					
0	59.0	14.7	0.5	15.2	-200.0
3500	46.5	12.9	1.0	13.9	1500
6500	35.8	11.6	1.5	13.1	3000
9500	25.1	10.3	1.8	12.1	5000
17000	-1.6	7.6	2.3	9.9	10500
18000	-5.2	7.3	2.4	9.7	11000
19000	-8.8	7.0	2.6	9.6	11500
19500	-10.5	6.9	2.7	9.6	11250
20000	-12.3	6.8	2.8	9.6	11250
20500	-14.1	6.6	3.0	9.6	11250
DESCENT					
20000	-12.3	6.8	2.8	9.6	11250
19500	-10.5	6.9	2.7	9.6	11250
19000	-8.8	7.0	2.6	9.6	11500
18000	-5.2	7.3	2.4	9.7	11000
17000	-1.6	7.6	2.3	9.9	10500
14000	7.3	8.5	1.8	10.3	9000
12000	14.4	9.2	1.6	10.8	7800
9500	25.1	10.3	1.5	11.8	5500
7000	32.3	11.1	1.1	12.2	4500
4000	43.0	12.5	0.7	13.2	2500
0	57.2	14.7	0.5	15.2	-200.0

FIGURE 11. Essential Pressure Data for Test Flight 2014-1.

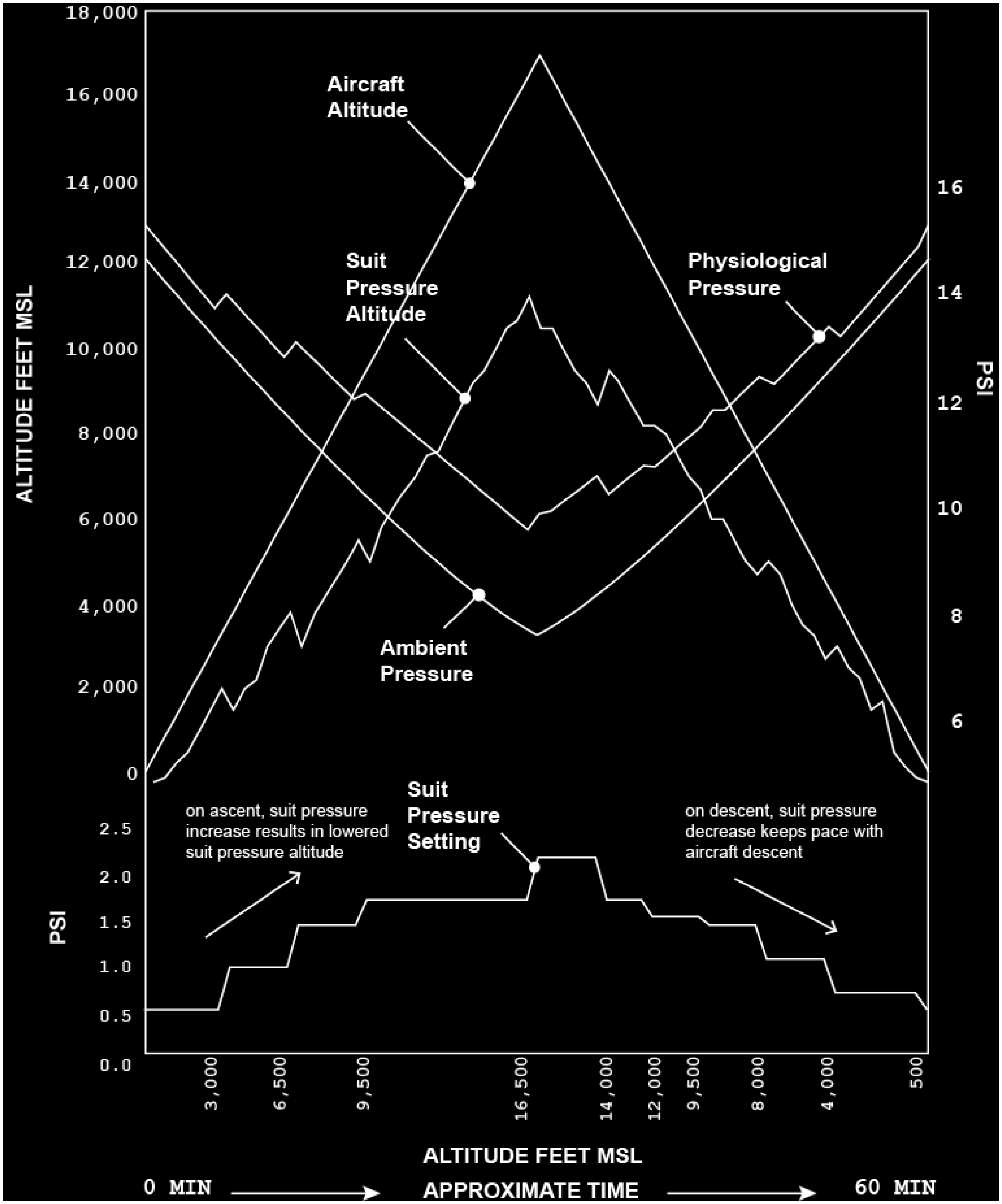

FIGURE 12. Carbon Dioxide Levels and Impairment Effects, 600 PPM – 2,500 PPM (from Satish et al. 2014). Note that effects differ not only by C02 level but also by variety of cognitive action; nevertheless, levels below 600PPM may be considered generally acceptable and levels above 1,000 PPM may be considered generally unacceptable.